NOTE ON ANORTHOCLASE FROM NIGERIA

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(*With Plate* 6)

THE anorthoclase which is the subject of this account occurs as large rhomb-shaped phenocrysts in a soda-trachyte. This rock outcrops on the steeper eastern and southern flanks of a gently sloping hill, which rises about 200 feet above the general level of the plateau, in latitude 9° 23′ N., longitude 8° 58′ E. near the centre of Nigeria, in the Plateau Province.

The specimens were collected in 1942 by the first-named author and presented to the Museum in 1949 (registered number B.M. 1949,25). At the time of this visit it was not realized that the rock had not previously been described and the outcrop was not examined in detail. The largest crystal collected measures about $10 \times 4\frac{1}{2} \times 6$ cm., but much larger specimens occur.

These anorthoclase phenocrysts, together with microphenocrysts of soda-pyroxene, are embedded in a trachytic groundmass of anorthoclase prisms showing well-developed flow structure. The presence of xenocrysts of andesine and spongy areas of quartz, riebeckite, and magnetite is evidence of the contamination of this rock from at least two different sources. The anorthoclase prisms of the groundmass are twinned on the Carlsbad law; $\gamma = 1{\cdot}536$; $2V_{(\alpha)} = 57°$ (mean of seven determinations). The andesine xenocrysts have the composition $Ab_{57}An_{43}$ and contain rod-like inclusions, probably rutile, which lie parallel to one another and to the *c*-axis of the feldspar. These andesines are surrounded by a rim of anorthoclase 0·1 to 0·2 mm. wide.

TABLE 1. *Chemical Analysis*

Anorthoclase from central Nigeria (B.M. 1949,25). (Analyst J. R. F. Joyce)

Analysis		*Atomic ratios*		*No. of metal atoms on basis of 32 O*	
SiO_2	65·86	Si	1·0975	11·66	} 16·00
Al_2O_3	20·66	Al	0·4051	4·30	
Fe_2O_3	0·29	Fe	0·0036	0·04	
FeO	0·10	Fe	0·0014	0·02	} 4·01
MnO	Tr.				
MgO	0·12	Mg	0·0030	0·03	
BaO	0·12	Ba	0·0008	0·01	
CaO	1·50	Ca	0·0268	0·28	
K_2O	3·88	K	0·0825	0·87	
Na_2O	8·17	Na	0·2635	2·80	
H_2O	0·17	O	3·0130		32·00
	100·87				

Sp. gr. (d_4^{20}) $2{\cdot}587 \pm 0{\cdot}010$ (by floatation method, using mixtures of bromoform and alcohol).
Molecular composition; Or 22·6, Ab 72·3, An 4·9, Cn 0·2 per cent.

Chemical composition

The chemical analysis of a hand-picked sample of the feldspar of the phenocrysts is given in Table 1, together with the atomic ratios and unit cell contents, calculated

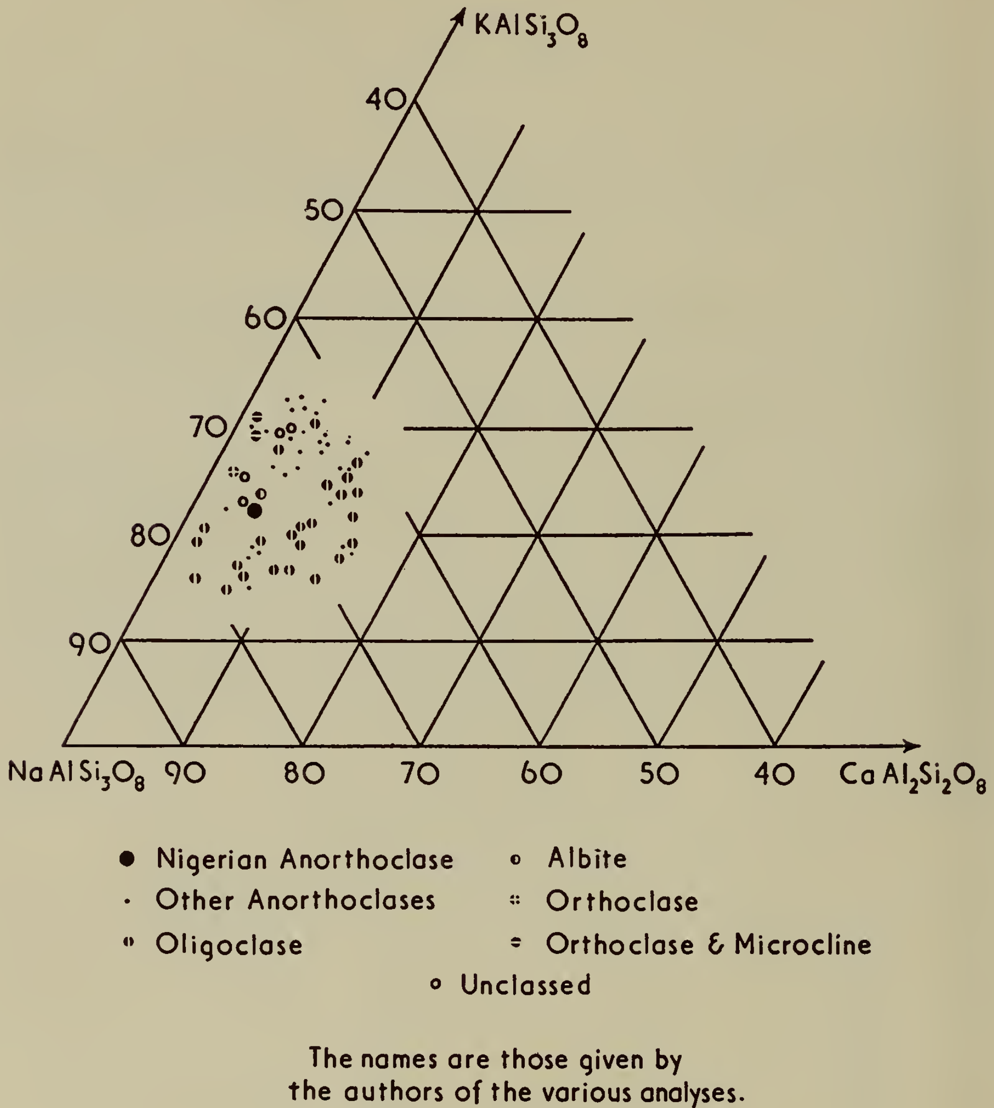


FIG. 1.

on a basis of 32 oxygen atoms. The analysis shows that the feldspar falls well within the anorthoclase field having the composition $Ab_{72\cdot3}Or_{22\cdot6}An_{4\cdot9}$. It contains 0·2 per cent. of the celsian molecule. In Fig. 1 the composition is shown in the form of a triangular diagram, in which plots of analyses of similar feldspars have been included.

The diagram shows that feldspars of comparable composition have mainly been termed anorthoclase or oligoclase by those who described them.

Optical properties

Table 2 gives the result of the optical determinations.

TABLE 2. *Optical Data*

α	= 1·5275 (Na-light)
β	= 1·5334 ,, ,,
γ	= 1·5349 ,, ,,
$2V_{(\alpha)}$ (measured)	= $52\frac{1}{2}°$ [$\rho > V$]
$2V$ (calculated from values of α, β, and γ)	= 53° 18′
(001) ^ (010)	= 89° 09′
α' ^ (001) on (010) cleavage flakes	= 5°·9 (mean of 9 values ranging from 4°·6 to 6°·8)
α' ^ (010) on (001) cleavage flakes	= 0°·8 (mean of 3 values ranging from 0°·0 to 1°·8)
α ^ [100]	= 8°
γ ^ [010]*	= 5°

* The position of [010] was obtained on the assumption of a value for the interfacial angle (001) ^ (100) of 116°.

Refractive indices were determined on polished surfaces in sodium light and with an Abbé-Pulfrich refractometer, previously calibrated against glass of known index and against quartz.

The value given for the cleavage angle was obtained as the mean of five determinations on a selected fragment using a Fuess single-circle goniometer. Good signals were obtained from (001), but signals from (010) were less precisely defined.

Extinction angles were measured on flakes obtained from a crushed sample. (010) was found to be the direction of easier cleavage; at least 90 per cent. of the cleavage flakes obtained by crushing were found to be (010) flakes. They can be recognized by means of their fine, polysynthetic twinning and centred, obtuse bisectrix interference figures. (001) represents a much harder cleavage; (001) flakes often show undulose extinction; hence the extinction angles obtained on these flakes show greater variations in value than do those measured on (010). Some (001) flakes show both relatively broad, rather hazy twin lamellae and also fine lamellae, both sets being parallel to the (010) cleavage face.

The determinations of the optic axial angle were made on a Leitz four-axis universal stage.

Optical orientation and twinning

Examination of a thin section (section 1) cut approximately perpendicular to both cleavages revealed the presence of two sets of twin lamellae almost at right angles to each other (Pl. 6, Fig. 1). One set of lamellae (parallel to (010)) are too fine to permit the determination of optic vectors, although it proved possible to orient the composition plane. The other set of lamellae (approximately parallel to (001)) are of sufficient breadth (maximum 0·08 mm.) to allow their optical orientation to be determined on the universal stage. Some of these relatively broader lamellae are homogeneous, but

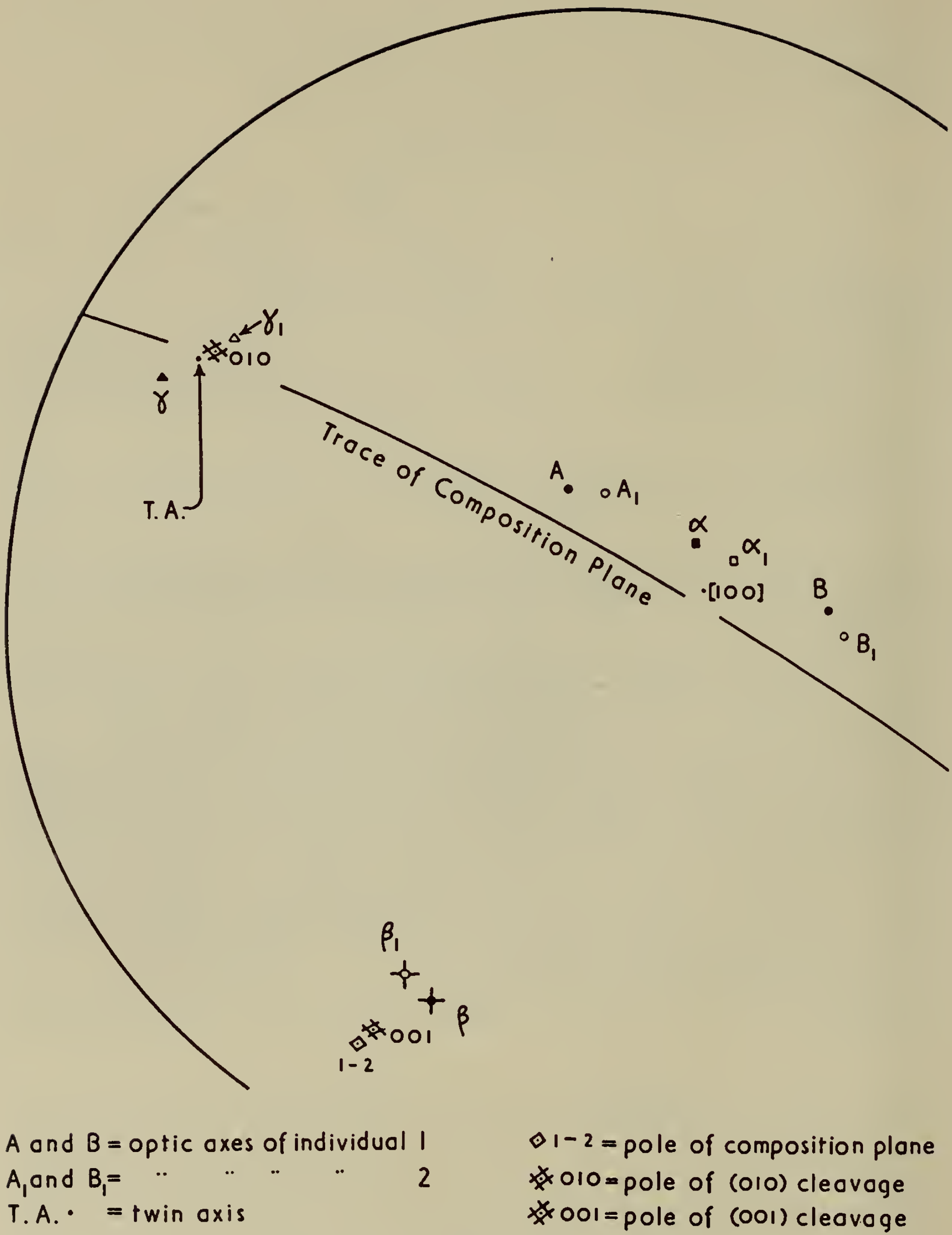

γ1
010
γ
T. A.
Trace of Composition Plane
A
A1
α
α1
·[100]
B
B1
β1
β
001
1 - 2
A and B = optic axes of individual 1
A1 and B1 = " " " " 2
T. A. · = twin axis
◇ 1 - 2 = pole of composition plane
010 = pole of (010) cleavage
001 = pole of (001) cleavage

FIG. 2.

others show very fine striations (Pl. 6, Fig. 2), parallel to the wider ones, which had to be disregarded in making the optical measurements. The stereogram of this section is shown in Fig. 2. When the plot of the first twin member is transposed so as to bring γ to the centre, the resulting positions of the poles of (001) and (010) (see Fig. 2*a*) closely correspond with the positions given by Emmons[1] for anorthoclase.

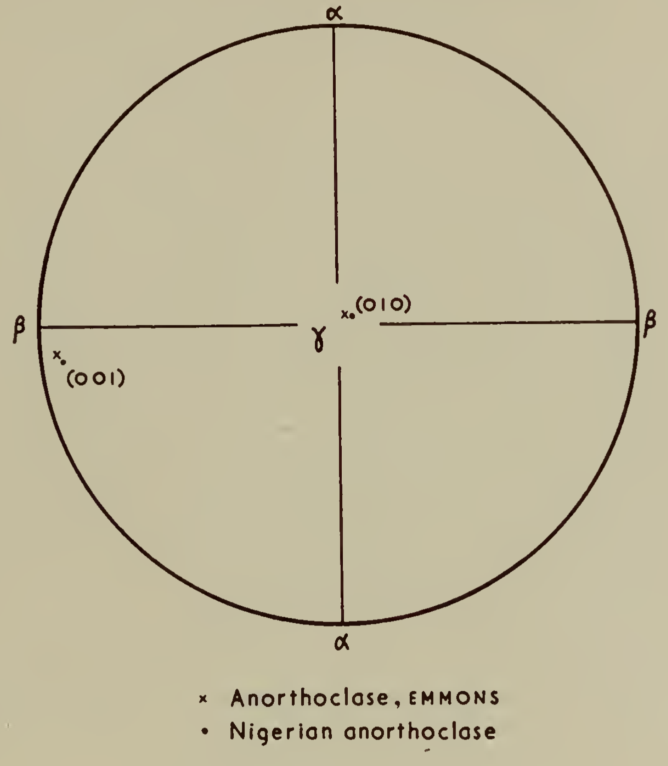


FIG. 2*a*.

The location, in the stereogram, of the twin axis in the composition plane is evidence of a parallel or complex twin law. Assuming an interfacial angle (001) ^ (100) of 116° it is possible to plot the zone axis [010] which lies at the intersection of the traces of the (001) and (100) planes. It is then found that [010] is, within the limits of plotting error, coincident with the twin axis. The stereogram also shows that the composition plane lies close to but does not coincide with (001), the angle between the two poles being about $2\frac{1}{2}°$. The twin axis lies within about 1° of the pole of (010). The evidence therefore indicates pericline twinning, the composition plane forming an angle of 2° to 3° with the (001) plane is the obtuse angle β (viz. +2° to 3° adopting the usual convention). Confirmation of the orientation of this composition plane was obtained by examining a section parallel to (010). On this section the trace of the composition plane was observed to make an angle of 3° with the trace of the (001)

[1] R. C. Emmons, 1943, The Universal Stage, *Mem. Geol. Soc. Amer.* 8, pl. 12, fig. 9.

cleavage. This angle differs by 9° from the mean angle quoted by Winchell[1] for pericline twins in anorthoclase, viz. −6°.

The orientation of anorthoclase is close to that of an oligoclase containing about 21 per cent. An. When therefore the stereogram (Fig. 2), after transposal to bring β to the centre, is superimposed on the appropriate Reinhard[2] diagram, the pole of (001) falls within 1 mm. of the migration curve for this pole (on the 20-cm. scale), whereas the (010) pole falls about 8 mm. below the (010) migration curve. From orientation measurements alone the distinction between anorthoclase and oligoclase might be open to doubt. Measurements of refractive indices and of $2V$ would, however, always distinguish between the two. The pericline composition plane for an oligoclase with 21 per cent. An would make an angle of about 6° with (001), a value not very different from that obtained for this anorthoclase, viz. +3°.

In section 1 (represented by Fig. 2) it was impossible to measure the optical orientation of the twinning lamellae which are perpendicular to the pericline lamellae and parallel to (010) because, as already stated, they are too narrow. However, a section approximately parallel to (001) (section 2) yielded some lamellae of sufficient width (up to 0·1 mm.) for optical determinations. Some of these relatively broader lamellae, like the pericline lamellae, show very fine parallel striations; others, while showing no twinning which can be resolved with the microscope, yet give incomplete or hazy extinction. The optical orientations of different pairs of twin lamellae in this section are not identical. The differences measured in three different pairs are shown in the three stereograms (*a*), (*b*), and (*c*) of Fig. 3. In the twin members represented by Fig. 3 (*a*) the extinction is approximately symmetrical with respect to the composition plane (010) and γ is inclined to the normal to (010) at 5°, this being the approximate value of the symmetrical extinction angle. In Fig. 3 (*b*) the extinction angles are still symmetrical but γ for each member of this twin pair is almost coincident with the normal to (010); the extinction angle is therefore almost zero. Fig. 3 (*c*) shows that this pair of twin lamellae have asymmetrical extinction. For one individual the value of $\gamma \wedge (010)$ is 6° while for the other it is almost zero. Extinction angles differing by 5° or 6° were observed in several twin pairs.

Fig. 3 (*d*) shows the stereogram of Fig. 3 (*a*) transposed so as to make the composition plane the plane of projection. The disposition of poles demonstrates the existence of a twin axis perpendicular to the plane of the figure, viz. perpendicular to (010), and shows that the twinning is albite.

The anomalous variations in the angles between conjugate poles for different twin pairs in the same section and the occasional asymmetrical extinction angles are thought to be due to the presence of submicroscopic twin lamellae in varying proportions (i.e. of different widths) in different lamellae.

A relatively broad lamella which is made up of fine (invisible) twin pairs of equal width would be expected to show (in the section perpendicular to (010) which we are considering) straight but incomplete extinction (Fig. 3 (*b*)). If, however, the visible lamella is composed of pairs of finer lamellae of very different widths, then its overall optical orientation will accord with that of the predominant member of these pairs.

[1] A. N. Winchell, *Elements of Optical Mineralogy*, 3rd edit., New York, 1933, part ii, p. 326.

[2] M. Reinhard, *Universal Drehtischmethoden*, Basel, 1931, pl. 2 [M.A. 4–435].

The extinction angle shown by the lamella then approaches the true value for this section. Asymmetrical extinction angles may then be explained by the different submicroscopic make-up of the two adjacent lamellae. Adjacent visible lamellae may thus show variations in both the size and symmetry of their extinction angles due to variations in the proportions of their invisible components.

The authors wish to express their best thanks to Dr. M. H. Hey both for supervising the analysis and for help in discussing the problem of anomalies in the twinning.

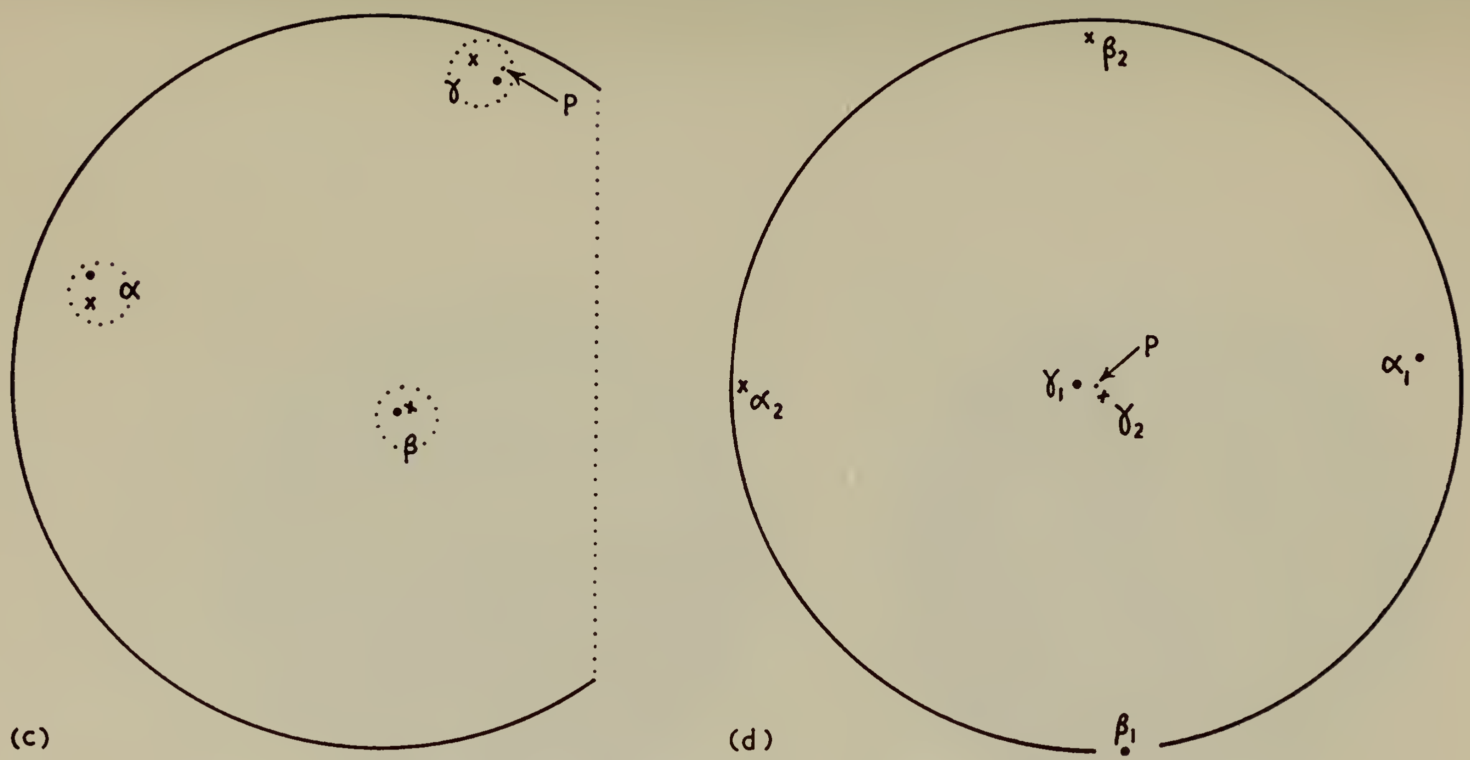
(a)

First pair of twin lamellae: joint width ·04 mm. extinction sharply defined, symmetrical.

(b)

Second pair of twin lamellae: joint width ·45 mm. extinction incomplete, symmetrical.

• = poles of twin member 1
× = " " " " 2
P = pole of composition plane



(c)

Third pair of twin lamellae : joint width ·10 mm. extinction asymmetrical

(d)

Transposed stereogram of figure 3(a). Plane of projection is the composition plane (010). Twin law is Albite law.

• = poles of twin member 1
x = " " " " 2
P = pole of composition plane

Fig. 3.

FIG. 1. Anorthoclase; section inclined at 20° to [100]
Polarized light; ×50

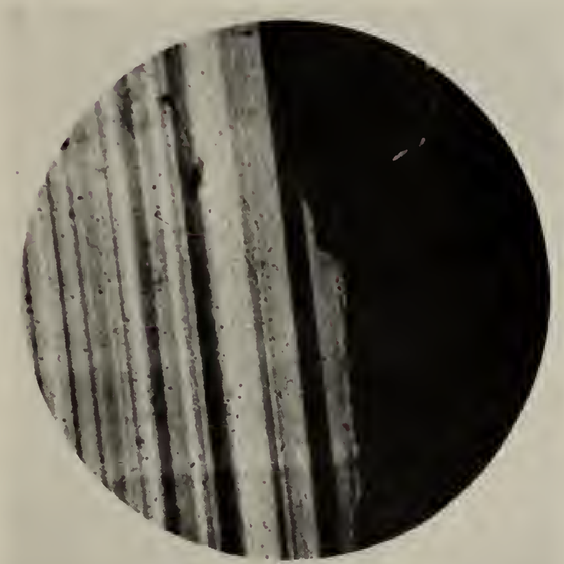


FIG. 2. Anorthoclase; same section as fig. 1, showing twin lamellae parallel to (001)
Polarized light; ×50